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Effects of Mobile Phone Signal Density on Communication: A Case Study at Thammasat Secondary School

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Abstract

This study compares the performance of Wi-Fi and 5G networks at Thammasat Secondary School, focusing on areas with high user density, such as classrooms, cafeterias, and sports fields. Signal quality was evaluated using the nPerf application, which measured key metrics, including download speed, upload speed, and latency during peak usage times.Data were collected at three different times of the day: morning, midday, and afternoon. The findings reveal that Wi-Fi outperforms 5G in terms of consistent download and upload speeds and lower latency in high-density regions. In contrast, 5G networks demonstrated higher speed fluctuations and increased latency, especially during peak usage times. This study suggests upgrading the school's network infrastructure, including the potential adoption of Wi-Fi 6 technology or a hybrid Wi-Fi/5G model, to improve overall performance, particularly in areas with high user congestion. Such improvements could support more reliable and efficient online learning activities and real-time communication within the school environment. Further research is recommended to explore the effects of network upgrades under varying conditions and over extended time periods.

Keywords: Wi-Fi, 5G, Network Density, Educational Networks, Latency, Throughput

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1. Introduction

The development of wireless communication technologies has influenced daily life in many ways, particularly in the field of education. Mobile phones and Internet access are now common tools that support both classroom learning and online education [1]. Alongside this trend, Wi-Fi and 5G technologies have been introduced to provide higher speed and efficiency to meet the increasing demand for data transmission [2, 3].

However, the concentration of users within limited areas, such as schools and universities, can lead to network congestion. This problem may reduce the quality of communication through slower download and upload speeds, higher latency, and interruptions during use [4]. Such issues are relevant in educational contexts, where reliable networks are important for learning and teaching [5].

Thammasat Secondary School makes extensive use of wireless networks for academic purposes. Teachers and students rely on mobile devices and computers to access online learning resources. Nevertheless, in some areas of the school, such as classrooms located far from access points or zones with high user density, the signal quality tends to decrease. These limitations may affect teaching and learning efficiency. Therefore, studying the impact of signal density across school areas is a useful approach for improving the performance of network systems [6].

This study aimed to evaluate the quality of mobile phone signals (Wi-Fi and 5G) at Thammasat Secondary School and assess how signal density affects communication quality in different school areas, such as classrooms, cafeterias, and basketball courts. This study aims to understand the impact of varying signal strengths on the performance of Internet-

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dependent educational activities, such as online learning and real-time communication between students and teachers. By comparing the performance of Wi-Fi and 5G networks in terms of download speed, upload speed, and latency, this study seeks to provide insights into how to optimize network infrastructure in high-density areas to effectively support educational needs.

2. Literature Review

Studies on mobile phone signal quality and the effects of user density in crowded areas have gained attention from researchers in various fields, especially in wireless communication. These technologies are widely used to meet the growing demand for data in the digital age. This review focuses on studies that measure and evaluate the quality of wireless networks such as Wi-Fi and 5G. It also examines the impact of user congestion in environments such as schools and universities, aiming to understand how these technologies are applied in educational settings.

2.1 Development of Wireless Networks and Technologies

Wireless networks began to develop in the 1990s with Wi-Fi, which became the standard for homes and workplaces. Wi-Fi improves wireless communication efficiency and supports higher data traffic. It has also enabled widespread use in schools and public areas. Subsequently, 5G was introduced to provide higher download speeds and lower latency. This technology further improves data access, particularly in areas with many users [7, 8].

2.2 Effects of User Density on Signal Quality

Several studies have investigated the effect of high user density on network performance. Wi-Fi and 5G networks often experience congestion in areas with many users, especially during peak periods such as lunch breaks. Adiba Abd Ghafar et al. found that increased user numbers significantly reduced Wi-Fi speed and caused delays in data downloads [9].

2.3 Effects of Signal Quality on Teaching and Learning

Signal quality is important in schools. Unstable connections can disrupt access to online learning materials and other Internet-dependent activities. Corredor Vallejo reported that poor Wi-Fi connectivity in classrooms and common areas delays access to educational content and negatively affects learning outcomes [10].

2.4 Strategies to Improve Wireless Networks for Education

Studies have proposed strategies for improving wireless network performance in schools. One approach is to add access points in weak-signal or high-traffic areas. Access control technologies can help manage the number of users in a system. Upgrading the Wi-Fi and 5G infrastructure can increase capacity and support future demands [6, 11, 12].

3. Research Methodology

This study employed a descriptive research design. The primary goal was to collect quantitative data on the quality of mobile phone signals (Wi-Fi and 5G) in various areas of the Thammasat Secondary School. The data collection focused on comparing the network performance and effects of user density. A signal measurement tool was used to record the download and upload speeds, as well as latency.

3.1 Data Collection

Data were collected in multiple locations, including classrooms, school buildings, cafeterias, and basketball courts. Measurements were taken at three time points: morning (08:00), midday (12:00), and afternoon (16:00), to compare the network quality across different periods. The collected data included download speed, upload speed, latency, and Internet usage performance, such as web browsing and streaming. The nPerf application was used as the measurement tool because it can accurately measure download and upload speeds as well as latency.

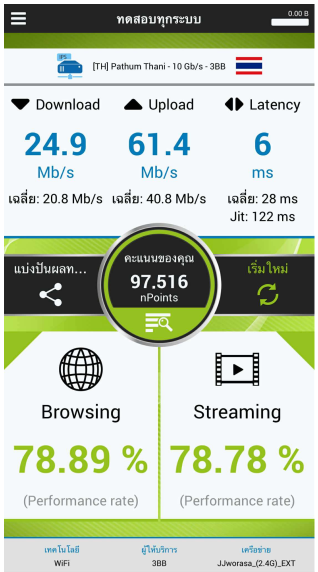

Figure 1. nPerf application.

3.2 Study Areas

This study focused on areas with high network usage. These included classrooms in buildings A B, and C; the cafeteria; the basketball court during breaks; and the main halls of buildings A and B. The locations were selected based on consistent daily network usage. Data were collected during class hours lunch breaks, and the afternoon period to examine the effects of user density at different times of day.

Figure 2. Thammasat secondary school**.**

3.3 Data Analysis

The collected data were analyzed using basic statistical techniques. The mean was calculated to show the general trends in the data. A correlation analysis was conducted to examine the relationship between the signal speed and latency.

4. Results

This study collected data on the signal quality in different areas of the Thammasat Secondary School. The analysis focused on comparing the performances of Wi-Fi and 5G networks. The key indicators included download speed, upload speed, latency, browsing performance, and streaming performance at different times of the day.

4.1 Comparison of Signal Performance in Different Areas

Measurements showed that Wi-Fi generally outperformed 5G in several areas, especially in terms of download speed and lower latency. This was particularly evident in the cafeteria, basketball court, and classrooms near the access points. The average results are presented in Table 1.

Table 1. Comparison of Wi-Fi and 5G network quality (average) in different areas.

Area	Wi-Fi	5G
Cafeteria	Download: 196.29 Mbps Upload: 129.51 Mbps Latency: 5.29 ms Browsing: 79.79% Streaming: 90%	Download: 114.71 Mbps Upload: 8.01 Mbps Latency: 25.43 ms Browsing: 65.59% Streaming: 79.51%
Basketball Court	Download: 161.46 Mbps Upload: 105.88 Mbps Latency: 4.8 ms Browsing: 83.15% Streaming: 93.49%	Download: 176.47 Mbps Upload: 21.03 Mbps Latency: 24.67 ms Browsing: 76.28% Streaming: 86.84%
Classrooms (Buildings A, B, C)	Download: 193 Mbps Upload: 120 Mbps Latency: 5 ms Browsing: 74.01% Streaming: 93.45%	Download: 110.13 Mbps Upload: 11.83 Mbps Latency: 24.3 ms Browsing: 70.54% Streaming: 87.23%

The comparison indicates that Wi-Fi is more stable and performs better in supporting many users. It is suitable for environments that require fast and reliable connections, such as cafeterias, basketball courts, and heavily used classrooms.

4.2 Effects of Usage Time on Connection Performance

The study examined the Wi-Fi and 5G network performance at three different times: 08:00, 12:00, and 16:00. The results showed that high user density during lunch hours (12:00) significantly affected connection quality. Differences in the performance of Wi-Fi and 5G were observed, as summarized in Table 2.

Table 2. Effects of usage time on network performance.

Time	Wi-Fi	5G
08:00	Download: 165.71 Mbps Upload: 114.5 Mbps Latency: 5.34 ms Browsing: 77.58% Streaming: 91.54%	Download: 158.55 Mbps Upload: 12.18 Mbps Latency: 23.35 ms Browsing: 72.06% Streaming: 85.39%
12:00	Download: 164.73 Mbps Upload: 125.66 Mbps Latency: 6 ms Browsing: 78.48% Streaming: 91.56%	Download: 112.91 Mbps Upload: 10.15 Mbps Latency: 24.31 ms Browsing: 72.82% Streaming: 84.44%

Time	Wi-Fi	5G
16:00	Download: 167.31 Mbps Upload: 111.41 Mbps Latency: 5.35 ms Browsing: 78.36% Streaming: 91.8%	Download: 110.16 Mbps Upload: 13.9 Mbps Latency: 25.12 ms Browsing: 70.83% Streaming: 84.34%

The analysis indicates that Wi-Fi maintained a stable performance across all time periods, even during high-usage times, such as 12:00. In contrast, 5G, while fast at certain times, shows higher latency during peak usage. This results in a lower overall performance during periods of heavy network traffic.

4.3 Correlation Analysis and Hypothesis Testing

This study conducted hypothesis testing and correlation analysis among several variables, including download speed, upload speed, latency, and browsing and streaming performance. The results show significant relationships between these variables (Table 3). The key findings are as follows.

Table 3. Correlation analysis between variables.

Variable	Wi-Fi (r)	5G (r)
Download Speed	Browsing Performance (0.82) Streaming Performance (0.80)	Browsing Performance (0.87) Streaming Performance (0.82)
Upload Speed	Browsing Performance (0.20) Streaming Performance (0.32)	Browsing Performance (0.19) Streaming Performance (0.34)
Latency	Download Speed (-0.75) Upload Speed (-0.71)	Download Speed (-0.64) Upload Speed (-0.58)
Browsing Performance	Download Speed (0.82)	Download Speed (0.87)
Streaming Performance	Download Speed (0.80)	Download Speed (0.82)

The key findings are as follows:

1. **Download Speed**
- Wi-Fi: Strongly correlated with browsing (r = 0.82) and streaming performance (r = 0.80).
- 5G: Strongly correlated with browsing (r = 0.87) and streaming performance (r = 0.82).
2. **Upload Speed**
- Wi-Fi: Weak correlation with browsing (r = 0.20) and streaming (r = 0.32).
- 5G: Moderate positive correlation with browsing (r = 0.19) and streaming (r = 0.34).
3. **Latency**
- Wi-Fi: Negatively correlated with download speed (r = -0.75) and upload speed (r = -0.71).
- 5G: Negatively correlated with download speed (r = -0.64) and upload speed (r = -0.58).
4. **Browsing Performance**

- Wi-Fi: Increases as download speed rises (r = 0.82)
- 5G: Increases as download speed rises (r = 0.87)

5. **Streaming Performance**

- Wi-Fi: Increases as download speed rises (r = 0.80)
- 5G: Increases as download speed rises (r = 0.82)

These results confirm that download speed is the main factor affecting browsing and streaming performance. Latency negatively impacts both download and upload speeds, affecting the overall performance of both networks.

5. Discussion

The study revealed significant differences in the performance of Wi-Fi and 5G networks at Thammasat Secondary School, particularly in high-density areas such as classrooms, cafeterias and basketball courts. These differences can be attributed to several physical and network-related factors that affect the signal quality and network performance in densely populated environments.

One of the primary factors influencing performance is the frequency characteristics of each technology. Wi-Fi generally operates in the 2.4 and 5 GHz frequency bands. While these frequencies are effective in providing adequate coverage, they are more susceptible to interference and signal degradation in high-density areas, especially during peak usage times. The 2.4 GHz band is particularly highly congested, as many devices (such as Bluetooth and microwave ovens) operate on similar frequencies, leading to increased interference and reduced bandwidth [1]. In contrast, 5G networks typically operate on higher frequency bands (e.g., 3.5 GHz and, in some cases, millimeter waves), which offer higher bandwidth and faster speeds [2]. However, 5G performance can be affected by physical obstructions (such as buildings and trees) and network congestion during peak times when a large number of users are connected to the same cell tower. This can cause fluctuations in speed and increased latency, particularly in areas where the signal coverage is less consistent [8].

User density is another critical factor contributing to the observed differences. A high user density increases the load on the network, which can lead to congestion and competition for bandwidth. Wi-Fi, especially in environments like classrooms and cafeterias, is typically better equipped to handle high user density due to its ability to support multiple simultaneous connections without significant degradation in performance [10]. Wi-Fi networks also benefit from the presence of multiple access points (APs) distributed throughout the environment, which helps alleviate congestion and ensure more stable connections. However, although 5G is capable of providing fast speeds, it faces challenges in high-density areas where its capacity to handle a large number of simultaneous connections is limited. The higher latency observed in 5G during peak usage times is a direct result of network congestion, which impedes the delivery of real-time applications such as video streaming or online learning activities that require low latency for smooth performance [5].

Furthermore, the network architecture and infrastructure of both Wi-Fi and 5G systems play a role in their performance. Wi-Fi networks are designed to provide local coverage in confined spaces, such as classrooms or cafeterias, using a mesh or star topology that allows for more efficient data distribution [6]. However, this can still lead to signal degradation in areas far from the access points (APs), particularly if the APs are not optimally placed. However, 5G networks are designed for wide-area coverage, and although they offer high-speed connections, their coverage range can be limited by physical barriers, and their performance can drop significantly in areas with insufficient 5G infrastructure [7].

The findings highlight that while Wi-Fi offers more consistent performance in areas with high user density, 5G's performance can still be affected by a combination of network congestion, interference, and physical obstacles. These challenges emphasize the need for improved infrastructure, such as Wi-Fi 6 upgrades, better placement of access points, and potential integration of Wi-Fi/5G hybrid models to ensure that educational institutions can support a growing number of users and provide a stable, high-quality network environment for learning [12].

Such improvements could also support more reliable and efficient online learning activities and real-time communications within the school environment, especially during peak usage times [1]. Ensuring stable connectivity during these periods is crucial to maintaining the quality of learning experiences and minimizing interruptions in interactive educational activities [2].

6. Conclusion and Recommendations

This study compared the performance of Wi-Fi and 5G networks at Thammasat Secondary School, focusing on areas with high user density, such as classrooms, cafeterias, and basketball courts. The results showed that Wi-Fi consistently outperformed 5G, providing higher and more stable download and upload speeds, along with lower latency, making it better suited for high-density environments.

Although 5G has demonstrated high speeds in some areas, its performance is hindered by higher latency and network congestion, particularly in densely populated areas. These limitations can impact real-time applications, such as online learning, video conferencing, and interactive education, which require fast and stable connectivity. The findings emphasize the importance of network infrastructure that can handle high user density, ensuring that activities requiring low latency are performed smoothly without interruptions.

Based on these findings, it is recommended that educational institutions, especially those with high user densities, prioritize upgrading to Wi-Fi 6 to improve performance and reduce congestion. Wi-Fi 6 technology offers an enhanced capacity, enabling smoother communication and faster Internet access, even during peak usage times. Its advanced features, such as Orthogonal Frequency Division Multiple Access (OFDMA) and Multi-User Multiple Input, Multiple Output (MU-MIMO), will significantly improve efficiency and latency management during periods of high traffic, making it an ideal solution for crowded environments.

Additionally, adopting a hybrid Wi-Fi/5G model could enhance network capacity and ensure more reliable Internet access across different usage scenarios. This model would allow seamless switching between networks, providing stable connectivity during periods of heavy usage. Such upgrades could provide a more stable platform for online education and real-time communication, enhancing the learning experience across schools.

Furthermore, it is essential to increase the number of access points (APs) in high-density areas to improve the signal strength and coverage. Strategically placing APs in locations such as classrooms, cafeterias, and sports fields will help mitigate signal degradation and ensure more reliable Internet connections during peak usage times.

Network traffic management should also be implemented, prioritizing educational traffic, especially for online learning, video conferencing, and live streamed lessons. This would help ensure that critical educational services are prioritized, thereby reducing latency and improving overall performance.

Finally, further research is recommended to explore the long-term impacts of Wi-Fi 6 and 5G hybrid systems on educational outcomes, specifically in terms of student engagement, and academic performance. Investigating the effectiveness of hybrid systems in diverse school environments will help determine the most suitable solution for optimizing network performance and accommodating future technological demands.

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